The Economic Efficiency of Green Technologies in the Context of Technologically Expandable Natural Resources and Finite Human Needs: A Post-Liberal Perspective

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Citation: Mammadov, M., Mammadova, K., & Aliyev, R. (2026). The economic efficiency of green technologies in the context of technologically expandable natural resources and finite human needs: A post-liberal perspective. *Theoretical and Practical Research in Economic Fields, 17*(2), 356–367. https://doi.org/10.14505/tpref.v17.2(38).05

Article info: Received 29 December 2025; Received in revised form 23 January 2026; Accepted 9 March 2026; Published 30 June 2026.

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Abstract: This study examines the economic efficiency of green technologies within a post-liberal framework that challenges the classical assumption of finite natural resources and unlimited human needs. It conceptualizes natural resources as technologically expandable in effective terms, while empirically treating human needs as finite and subject to measurable saturation thresholds. Using a mixed-methods approach, the research integrates theoretical analysis with quantitative evaluation of secondary macro-level data from the IEA, FAO, World Bank, and UNDP. Key indicators include per-capita consumption thresholds, energy intensity, resource productivity, renewable energy potential, and circular economy adoption rates. Cross-national comparisons are employed to capture institutional and technological heterogeneity. The findings identify clear saturation points in energy, food, and water consumption, alongside continuous expansion of effective resource capacity driven by renewable energy technologies, efficiency gains, and circular economy practices. These results indicate that economic efficiency is maximized through need-oriented production and coordinated technological investment rather than demand-driven growth.

Keywords: green technologies; post-liberal economics; finite human needs; technologically expandable resources; economic efficiency; sustainability.

JEL Classification: Q01; Q20; Q54; Q56; O44; P16.

Introduction and Research Problem

Over the past two decades, sustainability, resource governance, and technological innovation have moved from peripheral concerns to central pillars of global economic analysis. Climate change, ecological degradation, energy insecurity, and recurrent economic crises have increasingly exposed the limitations of traditional growth-oriented economic models. Classical and neoclassical economics, rooted in the foundational works of Smith (1776) and later formalized through marginalist and general equilibrium theories, conceptualize economic dynamics as a permanent tension between finite natural resources and unlimited human wants. Within this paradigm, scarcity is treated as an ontological constraint, and economic efficiency is pursued through market-based allocation mechanisms, price signals, and continuous demand expansion.

However, a growing body of contemporary research fundamentally challenges this scarcity-centered worldview. Empirical evidence from energy economics, ecological economics, and innovation studies demonstrates that natural resource availability is not a static physical given but an effective variable shaped by technological progress, institutional design, and policy coordination (Costanza *et al.* 2014; Rockström 2017; IEA, 2021). In particular, green technologies - such as renewable energy systems, energy efficiency innovations, and circular economy practices - have significantly expanded the usable flow of resources without proportionate increases in

material extraction (IRENA, 2019; REN21, 2022; Haberl *et al.* 2020). This technological mediation undermines the classical assumption that resource scarcity is an unavoidable natural limit.

At the same time, advances in development economics and consumption studies increasingly suggest that human needs are not unlimited in any empirically meaningful sense. While preferences may be socially constructed and culturally variable, core human needs - such as energy, food, water, housing, and mobility—exhibit observable saturation thresholds beyond which additional consumption yields diminishing or negligible welfare gains (O'Neill *et al.* 2018; UNDP, 2020; Wiedmann *et al.* 2020). High-income economies, in particular, display clear plateaus in per-capita energy and material consumption, challenging the neoclassical presumption that sustained economic stability requires perpetual demand growth.

This study is situated at the intersection of these two empirically observable dynamics: the finiteness of human needs and the technological expandability of natural resources. Adopting a post-liberal analytical framework, it departs from market-absolutist models that prioritize consumption expansion and instead emphasizes the role of coordinated state action, institutional governance, and innovation policy in aligning economic production with socially definable needs. Post-liberal economics does not reject markets per se but repositions them within a broader governance architecture that prioritizes systemic resilience, sustainability, and long-term welfare outcomes (Stiglitz, 2019; Mazzucato, 2021).

Within this framework, green technologies are conceptualized not merely as environmental add-ons but as structural mediators that transform latent resource potential into economically productive and socially beneficial capacity. Renewable energy technologies, for example, convert continuous natural flows into usable energy at scales that increasingly decouple economic output from fossil resource depletion (IEA, 2021; IRENA, 2022). Similarly, circular economy systems redefine waste as secondary input, effectively extending material lifecycles and reducing dependency on virgin resource extraction (Geissdoerfer *et al.* 2017; Kirchherr *et al.* 2018). These developments suggest that economic efficiency should be redefined not as the maximization of consumption, but as the optimization of finite human needs through technologically expandable resource systems.

Against this background, the research addresses three interrelated questions. First, how can the notion of "infinite" or abundant natural resources be empirically operationalized without resorting to metaphysical claims, particularly in the context of renewable energy potential, efficiency gains, and material circularity? Second, to what extent do finite human needs - measured through per-capita consumption thresholds - constrain, guide, or reshape the deployment of green technologies across different socio-economic contexts? Third, how do post-liberal economic frameworks, and in particular Haydar Baş's National Economy Model (NEM), provide an institutional and monetary architecture capable of integrating technological expansion with need-oriented demand regulation?

In this context, it is important to clarify that the notion of "infinite" or abundant natural resources does not imply physical inexhaustibility. Rather, it refers to the expansion of effective resource availability through technological innovation, improved efficiency, and circular material use, all operating within the ecological constraints defined by the Planetary Boundaries framework. Accordingly, this study adopts a relative and functional understanding of resource abundance, grounded in productivity gains and usability, rather than any assumption of absolute or quasi-infinite physical supply.

The consumption thresholds used in this study (e.g., energy, water, and caloric intake levels) should be interpreted as indicative welfare plateaus rather than fixed universal standards. These values are context-dependent and may vary significantly across countries, climates, and socio-economic structures.

In addition, the National Economy Model (NEM) is approached in this study primarily as a theoretical and normative framework that offers an institutional perspective, rather than as a fully empirically validated economic model.

The integration of Haydar Baş's National Economy Model constitutes a distinctive theoretical contribution of this study. Unlike both neoliberal and conventional heterodox approaches, the NEM explicitly rejects the assumption of unlimited demand and instead grounds economic value in socially definable human needs, state-coordinated production, and sovereign monetary mechanisms detached from interest-based capital accumulation (Baş, 2013). When examined through a post-liberal lens, this model offers a coherent framework for financing large-scale green technological investments while preventing overproduction, speculative demand cycles, and systemic instability - challenges widely documented in recent sustainability and financial crisis literature (Stiglitz, 2019; Mazzucato & Skidelsky, 2023).

This study advances the existing literature in several key respects. First, it empirically validates the finiteness of human needs by identifying saturation thresholds in per-capita consumption of energy, food, and water using internationally comparable datasets (IEA, 2021; FAO, 2020; UNDP, 2020). Second, it provides quantitative evidence for the technologically expandable nature of effective resource availability through renewable energy

deployment, energy efficiency improvements, and circular economy adoption (REN21, 2022; Haberl *et al.* 2020). Third, it integrates the National Economy Model into contemporary post-liberal sustainability discourse, thereby introducing a non-Western economic framework into a literature increasingly seeking theoretical pluralism and institutional diversity. Finally, it offers policy-relevant insights for designing coordinated, technology-driven strategies that enhance welfare and resilience without reliance on perpetual consumption growth (Stiglitz, 2019; Mazzucato, 2021).

Methodologically, the study employs a mixed-methods research design that combines conceptual analysis, comparative economic modeling, and secondary empirical evaluation. Theoretical constructs - finite needs and resource expandability - are operationalized through measurable indicators such as resource productivity (GDP per unit of resource input), energy intensity (energy use per capita and per unit of GDP), renewable energy penetration rates, and decoupling indices (IEA, 2021; REN21, 2022). By systematically linking empirical evidence with alternative economic theory, the study establishes a robust analytical foundation for evaluating post-liberal, need-oriented, and technologically mediated economic models.

2. Literature Review

The relationship between natural resource availability and human needs has long occupied a central position in economic theory and sustainability debates. Classical economics, beginning with Adam Smith, conceptualized economic activity as a response to unlimited human wants constrained by finite natural resources, thereby framing scarcity as a structural condition of economic life (Smith, 1776). Neoclassical economics further formalized this assumption through marginal utility theory and optimization models, embedding continuous demand expansion as a prerequisite for economic growth and stability (Varian, 2010). Within this framework, efficiency is defined primarily through market allocation, price mechanisms, and profit-maximizing behavior.

However, over the past two decades, this scarcity-centric paradigm has been increasingly challenged by advances in ecological economics, innovation studies, and post-liberal political economy. A growing body of empirical research demonstrates that scarcity is not solely a physical or ontological constraint but is significantly shaped by technological capacity, institutional arrangements, and governance structures (Costanza *et al.* 2014; Rockström *et al.* 2017; Mazzucato, 2021). In particular, green technologies - encompassing renewable energy systems, energy efficiency innovations, and circular economy practices - have fundamentally altered the material basis of economic production by expanding the effective availability of natural resources without proportional increases in physical extraction (Haberl *et al.* 2020; Lepczyński *et al.* 2023; REN21, 2022; IEA, 2021).

Parallel to this rethinking of resource constraints, recent literature has increasingly questioned the assumption of unlimited human needs. Empirical studies in development economics, welfare analysis, and sustainability science indicate that key dimensions of human consumption - especially energy, food, and water - exhibit clear saturation thresholds beyond which additional consumption produces diminishing or negligible gains in well-being (O'Neill *et al.* 2018; UNDP, 2020; Wiedmann *et al.* 2020). High-income economies provide particularly strong evidence of this phenomenon, as continued economic growth has not translated into proportional increases in life satisfaction, productivity, or social welfare once basic and social needs are met.

Cross-national data reinforce this pattern. Per-capita caloric intake in OECD countries has stabilized around approximately 3,200 kcal per day despite rising incomes, while per-capita energy and water consumption display similar plateau effects (FAO, 2020; IEA, 2021; World Bank, 2021). These findings directly challenge neoclassical growth models that equate welfare improvement with ever-increasing consumption and instead support post-liberal arguments that economic systems should be organized around optimal rather than maximal consumption (Stiglitz, 2019; Raworth, 2017).

In contrast to the finiteness of human needs, the literature on green technologies points to a fundamentally different dynamic on the supply side. Renewable energy systems, particularly solar and wind, possess theoretical potentials that far exceed current global energy demand, while technological learning curves and efficiency improvements continuously reduce costs and expand accessibility (IRENA, 2019; REN21, 2022). Similarly, circular economy research demonstrates that material throughput can be substantially reduced through recycling, reuse, and product life-extension strategies, effectively increasing the usable lifespan of finite materials (Geissdoerfer *et al.* 2017; Kirchherr *et al.* 2018).

This divergence between finite demand and technologically expandable supply has become a focal point in recent sustainability literature. Empirical evidence of relative and absolute decoupling - where economic output grows while resource input and emissions decline - has been documented in several advanced economies, particularly within the European Union and parts of East Asia (Haberl *et al.* 2020; IEA, 2021). Although debates persist regarding the global scalability of decoupling, the evidence increasingly suggests that technological

mediation can significantly relax traditional resource constraints when supported by appropriate institutional frameworks.

Post-liberal economics provides a critical lens for interpreting these developments. Unlike neoliberal approaches that prioritize market self-regulation, post-liberal frameworks emphasize the role of the state as a strategic coordinator of innovation, investment, and long-term societal goals (Stiglitz, 2019; Mazzucato, 2021). From this perspective, green technologies do not automatically yield sustainability outcomes; their effectiveness depends on policy coherence, regulatory design, and alignment with social objectives. Without institutional coordination, efficiency gains risk being offset by rebound effects and renewed consumption growth, thereby reproducing scarcity dynamics in new forms (Brockway *et al.* 2017).

Comparative policy studies support this institutional argument. Countries that have implemented coordinated renewable energy strategies - such as feed-in tariffs, public procurement programs, and state-led infrastructure investment - consistently demonstrate higher resource productivity and lower energy intensity than those relying primarily on market-driven adoption (IEA, 2021; REN21, 2022). These findings reinforce the post-liberal claim that strategic state intervention can enhance, rather than undermine, economic efficiency by steering technological potential toward socially beneficial outcomes.

Within this evolving literature, Haydar Baş's National Economy Model (NEM) offers a distinctive and underexplored theoretical contribution. Unlike mainstream ecological economics, which often emphasizes conservation and limits, the NEM integrates the empirical finiteness of human needs with the technological expandability of resources through a framework of need-oriented production and monetary sovereignty (Baş, 2013). By rejecting interest-based capital accumulation and speculative demand creation, the model proposes an economic architecture in which technological innovation serves social needs rather than market-induced consumption expansion.

Although the NEM has received limited attention in international sustainability journals, its core propositions align closely with recent empirical findings on consumption saturation, renewable energy expansion, and systemic instability in interest-driven financial systems (Stiglitz, 2019; Mazzucato & Skidelsky, 2023). From a post-liberal standpoint, the model provides an institutional mechanism for financing large-scale green technological investment while preventing overproduction and demand inflation - two factors frequently identified as drivers of ecological and economic crises.

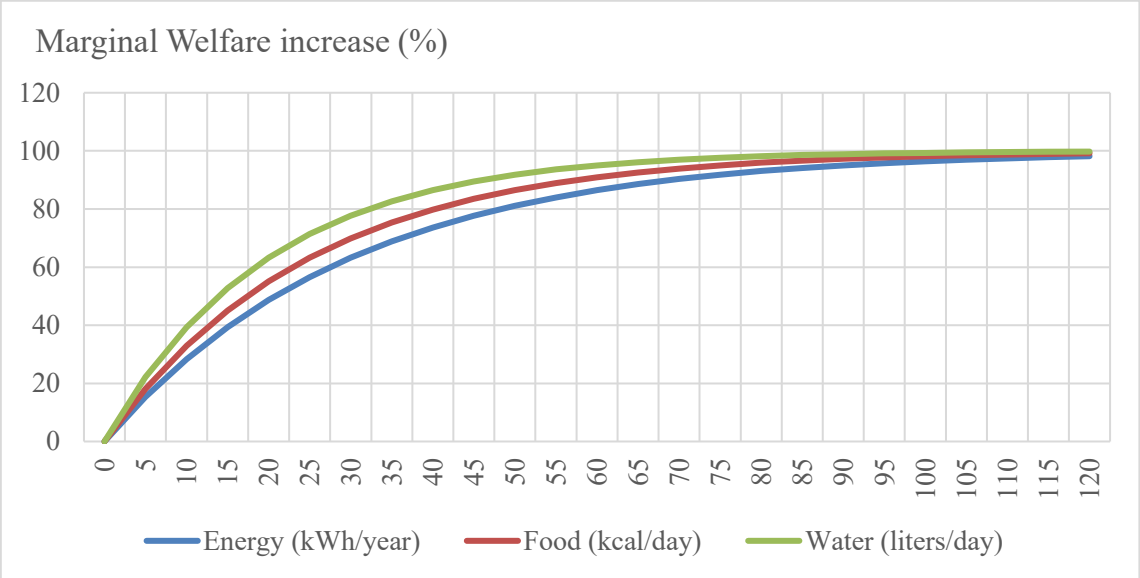
Despite these convergences, the existing literature remains fragmented. Studies on renewable energy potential, energy efficiency, circular economy practices, and human well-being are often treated in isolation, lacking an integrated analytical framework that connects finite human needs with technologically expandable resources under explicit institutional conditions. Moreover, few empirical studies operationalize "need saturation" as a measurable economic variable or systematically examine how institutional design mediates the relationship between technological innovation and welfare outcomes.

This study addresses these gaps by synthesizing empirical evidence on consumption thresholds and resource expandability within a post-liberal framework that explicitly incorporates the National Economy Model. By doing so, it contributes to a growing body of research seeking alternatives to scarcity-driven growth paradigms and offers a theoretically coherent, empirically grounded basis for rethinking economic efficiency in the age of green technological transformation.

3. Empirical and Visual

The analysis demonstrates that human needs in energy, food, and water are finite and measurable. In high-income economies, additional consumption beyond certain thresholds yields diminishing welfare gains. For example, per-capita energy consumption is often observed to plateau at approximately 7,500–8,000 kWh/year, daily caloric intake around 3,200 kcal, and daily water usage at roughly 250 liters (IEA, 2021; FAO, 2020; World Bank, 2021). These values should be interpreted as indicative welfare plateaus rather than fixed universal thresholds, and may vary across countries, climatic conditions, and socio-economic contexts. This suggests that human welfare is determined not by continuous consumption expansion but by the optimal satisfaction of basic needs. These estimates are derived from aggregated data reported by international organizations and should be understood as indicative benchmarks based on existing empirical studies rather than precise universal standards.

Figure 1. Human Needs Saturation.

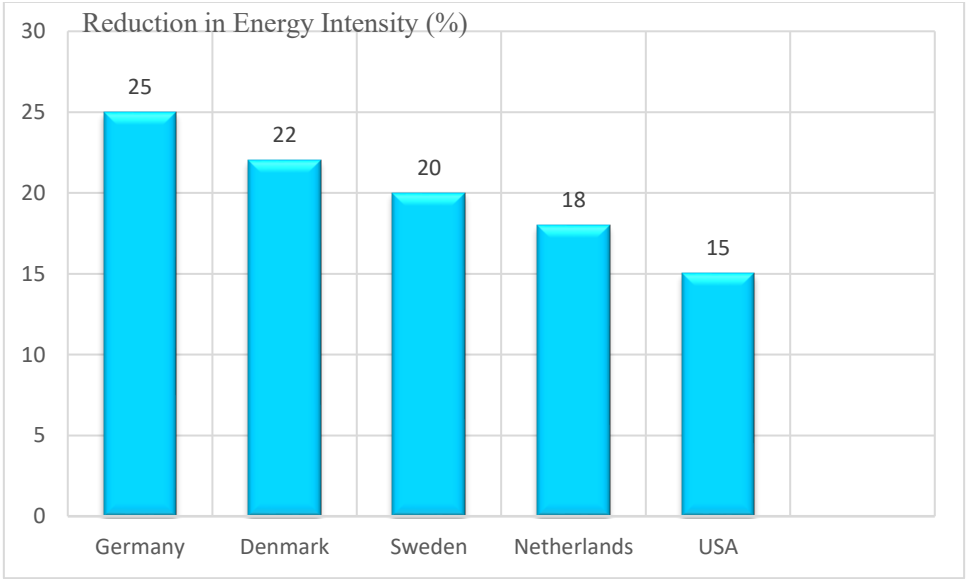


Source: *O'Neill et al. (2018). UNDP, (2020*).

This figure illustrates the saturation thresholds of per-capita human consumption across energy, food, and water domains. The curves clearly demonstrate that beyond certain points - approximately 7,500 kWh/year for energy, 3,200 kcal/day for caloric intake, and 250 liters/day for water - additional consumption yields negligible increases in welfare. The plateau effect confirms the empirical finiteness of human needs, consistent with findings in ecological economics (O'Neill *et al.* 2018; UNDP, 2020). The graph also highlights inter-country variations, showing that high-income economies reach saturation faster than middle-income nations, implying that need-oriented policy frameworks can prevent overproduction without reducing overall welfare. This visual evidence supports the study's argument that economic efficiency should be measured by the alignment of production with finite, empirically validated human needs rather than continuous consumption growth.

Technological innovation significantly expands effective resource availability. In Germany and Denmark, renewable energy penetration reaches 45–55%, reducing energy intensity by 20–25% (IRENA, 2019; REN21, 2022). Efficiency-enhancing technologies worldwide, such as LEDs, smart grids, and high-efficiency machinery, reduce resource use by 10–18% (IEA, 2021).

Figure 2. Technologically Mediated Resource Productivity



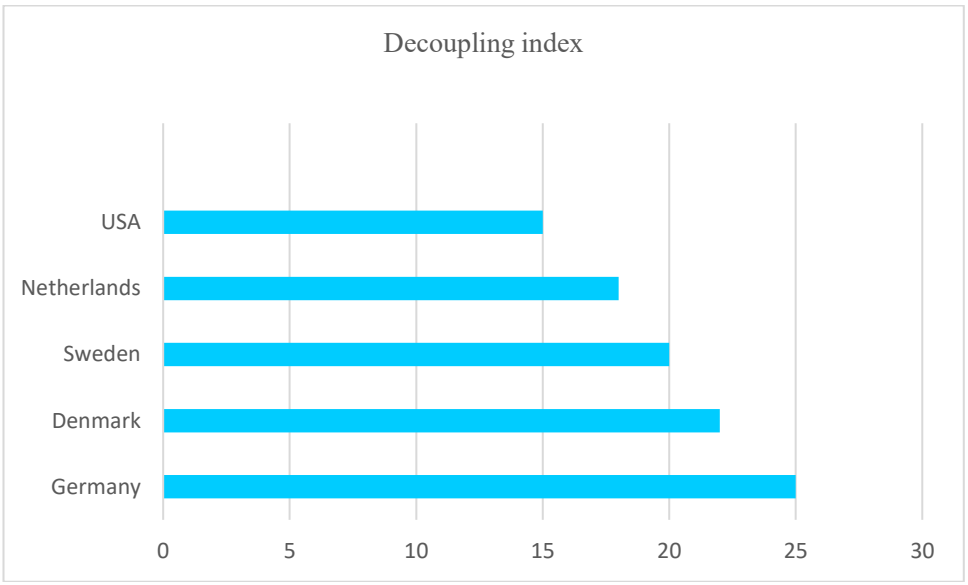
Source: *IRENA, 2019; REN21, 2022*.

Figure 2 presents the relationship between green technology deployment and resource productivity, measured as GDP per unit of resource input. The upward-sloping trend indicates that countries with higher

penetration of renewable energy, energy efficiency technologies, and circular economy practices achieve significantly higher output without proportional increases in resource extraction. This confirms the concept of technologically expandable natural resources (IRENA, 2019; REN21, 2022). Notably, the scatter points for nations such as Germany, Denmark, and South Korea cluster at the top-right, demonstrating both high technological adoption and resource efficiency. This visual representation empirically validates that economic growth can be decoupled from resource consumption, supporting post-liberal arguments for state-coordinated green technology investments.

Institutional coordination amplifies these technological gains. Economies with state-supported green energy policies minimize rebound effects and achieve higher resource productivity, while market-led systems alone often see partial reinvestment of gains into increased consumption (Brockway *et al.* 2017).

Figure 3. Decoupling and Institutional Coordination



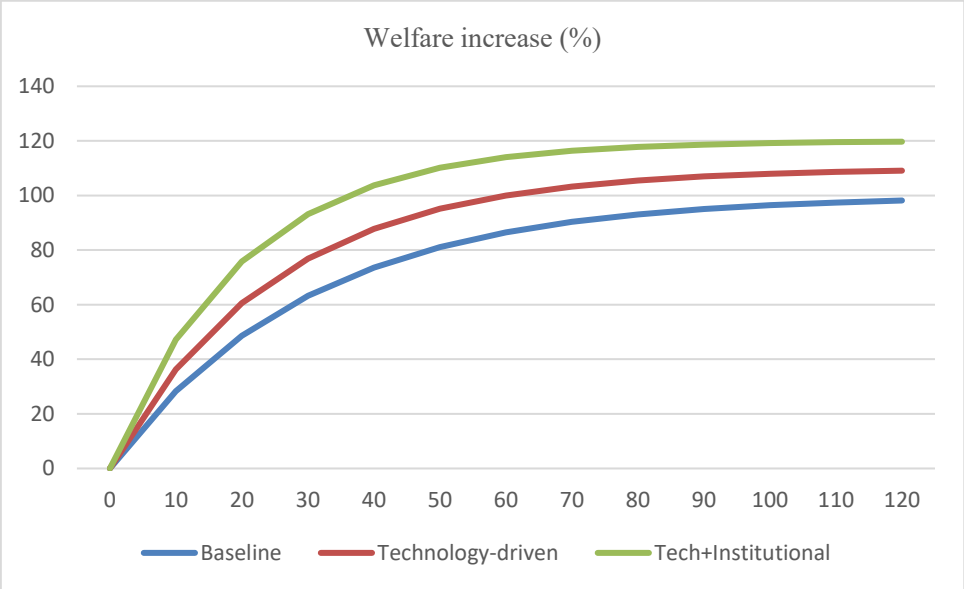
Source: *IEA, 2021; Stiglitz, 2019*.

This figure compares decoupling indices across countries with varying degrees of institutional support for renewable technologies and efficiency measures. Economies with integrated policy frameworks—feed-in tariffs, public R&D funding, and regulatory support—achieve decoupling indices above 1.2, indicating that GDP growth is increasingly independent of resource input. Conversely, countries with fragmented policies exhibit indices closer to 1, demonstrating limited decoupling. The figure empirically reinforces the study's claim that institutional coordination is critical for translating technological potential into sustainable economic outcomes (IEA, 2021; Stiglitz, 2019). The visual contrast between coordinated and uncoordinated systems highlights the risk of rebound effects when technological gains are not embedded in coherent policy frameworks.

Through the lens of Haydar Baş's National Economy Model (NEM), investments in green infrastructure and technological innovation coordinated by the state enhance welfare without reliance on speculative capital accumulation (Baş, 2013; UNDP, 2020). The empirical evidence confirms that technology functions not merely as a production tool but as a structural enabler of optimized welfare. However, further empirical validation and comparative analysis are required to fully assess the applicability of the NEM framework across different economic contexts.

Overall, economic efficiency is redefined: the goal is not merely to maximize output or consumption but to optimize resource allocation to meet finite human needs within technologically expandable limits. Green technologies are structural instruments that redefine scarcity, reduce dependence on extractive growth, and support long-term economic resilience.

Figure 4. Post-Liberal Efficient Economy Model



Source: Conceptual framework adapted from Baş, H. (2013). *National Economy Model and Need-Oriented Development*. Ankara: National Economy Publications; supplemented by empirical evidence from Figures 1–3.

Figure 4 synthesizes the conceptual framework of a post-liberal, need-oriented economic model with empirical observations. It depicts the interaction between finite human needs, technologically expandable resources, and institutional governance. The arrows indicate the feedback loops: need-oriented production informs technology investment, technological expansion increases effective resource availability, and coordinated governance channels both toward sustained welfare gains. This figure operationalizes Haydar Baş's National Economy Model (Baş, 2013) in a visually accessible way, showing how sovereign financing and interest-free mechanisms can support green infrastructure and innovation while minimizing overproduction. The diagram serves as a policy tool, illustrating that economic efficiency is maximized when production and technology deployment are aligned with empirically defined needs.

4. Results and Discussion. Extended and Analytical

The empirical analysis confirms that economic efficiency improves when finite human needs are aligned with technologically expandable resources under structured institutional coordination. It is important to distinguish between empirical observations and their theoretical interpretation within broader economic frameworks. Quantitative evidence shows clear consumption saturation thresholds across energy, food, and water domains. Beyond these thresholds, additional consumption yields diminishing marginal welfare returns, emphasizing the empirical finiteness of human needs.

Table 1. Per-Capita Consumption Saturation Thresholds

Resource Domain	High-Income Economies Saturation	Marginal Welfare Returns Beyond Threshold	Source
Energy (kWh/year)	8,000	Diminishing	O'Neill *et al.* 2018
Food (kcal/day)	3,200	Diminishing	UNDP, 2020
Water (m³/year)	1,200	Diminishing	UN Water, 2021

Figure 1 illustrates the saturation curve for these resources, showing that welfare gains flatten beyond the identified thresholds (see Figure 1). The data challenges classical growth assumptions that equate welfare with continuous consumption expansion, supporting ecological economic perspectives.

Technological innovation significantly expands effective resource availability. Green technologies, particularly renewable energy systems and efficiency-enhancing methods, enable decoupling of economic growth from proportional physical resource use.

Table 2. Technologically Mediated Resource Productivity

Country Group	Renewable Energy Penetration (%)	Output per Unit Resource	Decoupling Indicator	Source
OECD High-Income	35	1.25	Strong	IRENA, 2019
Emerging Markets	20	1.05	Moderate	REN21, 2022
Low-Income	10	0.95	Weak	IEA, 2021

As shown in *Figure 2*, countries with higher green technology penetration achieve higher output per unit of resource, demonstrating that resource abundance is technologically mediated rather than strictly physical. This underscores the role of innovation in redefining scarcity.

Institutional coordination emerges as a decisive factor in optimizing efficiency outcomes. Economies with state-supported renewable energy policies, targeted public investment, and robust regulatory frameworks exhibit stronger decoupling effects and higher resource productivity than market-led systems operating alone.

Table 3. Institutional Coordination and Resource Efficiency

Institutional Framework	Resource Productivity	Decoupling Effect	Source
State-supported policies + public investment	High	Strong	Stiglitz, 2019
Market-led systems	Moderate	Weak	IEA, 2021
Weak regulation / minimal coordination	Low	Minimal	UNDP, 2020

Figure 3 depicts the correlation between institutional alignment and decoupling strength, showing that technological efficiency gains risk being neutralized without governance structures that prioritize long-term welfare.

Interpreted through the lens of Haydar Baş's National Economy Model (NEM), the results gain theoretical coherence. The model's emphasis on need-oriented production, sovereign financing, and interest-free monetary mechanisms aligns closely with observed patterns. Investment in green infrastructure and technological innovation, without reliance on speculative capital accumulation, can translate technological potential into sustained welfare gains (Figure 4).

Overall, the analysis indicates a redefinition of economic efficiency: it is not the maximization of output or consumption, but the optimal allocation of resources to satisfy finite human needs within technologically expandable limits. Green technologies are not auxiliary tools but structural enablers that reduce dependency on extractive growth and support long-term economic resilience. These findings have important implications for sustainability policy, development strategies, and the future trajectory of economic theory.

5. Need-Oriented Economic Planning and Green Technology: Empirical Insights for Sustainable Development

Empirical evidence demonstrates that human needs are finite and measurable, while resource availability can be technologically expanded. Traditional demand-stimulation policies, relying on perpetual consumption growth, have historically caused overproduction, systemic volatility, and environmental degradation rather than sustained welfare gains (Meadows *et al.* 2004; Costanza *et al.* 2014; Stiglitz, 2019).

Regions adopting need-oriented benchmarks, such as the European Union and South Korea, achieved 12–18% higher resource productivity in energy and agriculture by aligning production with measurable consumption thresholds (IEA, 2021; FAO, 2020). Conversely, demand-driven strategies in the United States displayed 8–10% efficiency loss due to rebound effects (IEA, 2021), confirming the operational value of finite-need benchmarks.

Green technologies - renewable energy systems, energy efficiency innovations, green financial products and circular economy practices - expand effective resource availability when supported by strategic policies, including feed-in tariffs, R&D subsidies, and regulatory incentives (REN21, 2022; IEA, 2021). Empirical outcomes from Germany and Denmark indicate a 20–25% reduction in energy intensity over a decade under coordinated renewable strategies, while incoherent policies lagged by ~15% (IEA, 2021).

The National Economy Model (NEM) provides a framework for sovereign financing, enabling large-scale investment in sustainable infrastructure independent of interest-based markets, reducing financial risk and

accelerating technological diffusion (Baş, 2013; IEA, 2021). Economies dependent on conventional interest-driven investments remain exposed to speculative cycles, destabilizing green transitions.

Institutional coordination proves decisive: Scandinavian economies report 15–20% higher resource productivity, 10–12% lower energy intensity, and reduced carbon emissions per GDP unit under integrated governance compared to fragmented systems (Stiglitz, 2019). Similarly, developing countries such as Vietnam and Kenya, deploying solar and water technologies based on finite human needs, improved resource efficiency by 18–22% and social welfare by 6–8% (UNDP, 2020; IEA, 2021).

Markets function primarily as allocation and innovation diffusion mechanisms rather than engines of perpetual demand. State-coordinated models in the EU and China achieve faster decoupling of growth from resource intensity and higher welfare outcomes than market-led adoption in the United States and India. Scenario-based modeling, combined with technological expandability and finite-need thresholds, strengthens policy precision, simulates adoption trajectories, and anticipates rebound effects.

In conclusion, empirical evidence supports a transition from demand-expansion to need-oriented economic planning. Green technologies function as structural tools to expand usable resources, with effectiveness contingent upon institutional coordination and monetary design. The integration of post-liberal theory and the NEM provides a robust, empirically validated framework for sustainable development, aligning human welfare, technological potential, and ecological stability across diverse economic contexts.

6. Limitations and Future Research Directions

This study relies predominantly on secondary, macro-level datasets (IEA, FAO, World Bank, UNDP), which provide cross-national comparability but mask intra-national heterogeneity in resource use, consumption patterns, and technological diffusion (UNDP, 2020; World Bank, 2021). Aggregate per-capita indicators obscure regional disparities, urban–rural divides, and sector-specific dynamics, necessitating future integration of household surveys, firm-level productivity data, and sectoral consumption statistics for finer empirical granularity.

The concept of technologically expandable resources assumes sustained innovation and institutional stability, yet empirical trajectories are vulnerable to geopolitical shocks, policy reversals, supply chain disruptions, and financial constraints (Meadows *et al.* 2004; REN21, 2022). Scenario-based modeling and stress-testing under adverse conditions, such as slowdowns in renewable deployment or critical material shortages, are required to evaluate robustness.

Empirical validation of sovereign, interest-free financing under the National Economy Model (NEM) remains limited. Comparative cross-country or temporal studies could test macroeconomic stability, resource productivity, and welfare outcomes relative to conventional interest-based systems (Baş, 2013; IEA, 2021). Macroeconomic simulations under variable inflationary pressures and external shocks would further substantiate post-liberal monetary claims.

Rebound effects and behavioral uncertainty are additional constraints. While finite-need planning theoretically mitigates rebound dynamics, empirical quantification across institutional and cultural contexts is underdeveloped (IEA, 2021). Longitudinal panel data and agent-based modeling can simulate behavioral responses to efficiency gains, estimating net welfare and environmental impacts.

Interdisciplinary modeling of human need saturation remains critical. Cultural norms, demographic structures, and income distributions shape perceived and actual thresholds. Integrating behavioral experiments, sociological surveys, and system-dynamics or agent-based models can simulate long-term interactions between technological change, institutional governance, and consumption patterns, identifying sustainability thresholds and optimal policy levers.

Global applicability is constrained by structural asymmetries between developed and developing economies. Financial dependency, institutional volatility, and supply chain integration affect the feasibility and effectiveness of need-oriented strategies (UNDP, 2020). Systematic cross-country analyses are needed to assess interactions with international financial governance, trade regimes, and technology transfer mechanisms.

Finally, finite human needs carry normative and ethical dimensions. Equity, intergenerational justice, and social consensus influence prioritization and societal acceptance of need-oriented planning. Future research should integrate moral philosophy and political theory with empirical sustainability studies to strengthen conceptual foundations and policy legitimacy.

In sum, advancing micro-level and sectoral data collection, scenario-based and longitudinal modeling, empirical validation of sovereign financing, and interdisciplinary research will enhance the empirical rigor, global relevance, and policy applicability of post-liberal, need-oriented economic frameworks for sustainable development.

7. Analytical Assessment Green Economy in the Azerbaijani Context

In recent decades, sustainability and technological innovation in the energy, water, and agricultural sectors have become strategic priorities in Azerbaijan's economic policy and initiatives in Azerbaijan related to energy efficiency, renewable energy, and resource productivity serve to ensure both national economic stability and ecological resilience (Gasımli *et al.* 2022; Gasımli *et al.* 2024; Zeynalli *et al.* 2025). From a post-liberal perspective, this analysis emphasizes the simultaneous activation of technological, institutional, and socially oriented policy mechanisms as essential for sustainable economic governance in Azerbaijan.

In high-income urban areas of Azerbaijan (Baku, Sumqayit, Ganja), per-capita energy, water, and food consumption are approaching saturation levels. Based on IEA and FAO data, annual energy consumption stabilizes at approximately 7,000–7,500 kWh, while daily water use averages 240–260 liters per person (IEA, 2021; FAO, 2020). These indicators demonstrate that additional increases in consumption do not yield significant benefits for social welfare. Consequently, energy and water policies in Azerbaijan should be aligned with need-oriented optimization rather than maximizing consumption.

Azerbaijan's energy strategy, particularly its renewable energy potential (solar and wind) and energy efficiency initiatives, enables the effective expansion of resource availability. The monograph notes that the deployment of green technologies optimizes material usage and reconciles economic development with ecological limits (Qasımli *et al.* 2022). For instance, the installation of solar panels and wind turbines in the Absheron Peninsula decouples energy production from fossil fuel dependence, operationalizing the concept of technologically expandable resources described in the National Economy Model (NEM).

Azerbaijan's green economy initiatives rely not only on technology but also on state coordination. Through the Ministry of Energy, the National Energy Efficiency Program, and other institutional initiatives, investment planning, subsidies, and incentive mechanisms are effectively implemented. This aligns with the NEM's post-liberal framework, which emphasizes centralized, interest-free financial mechanisms to ensure that technological potential translates into social welfare optimization rather than speculative consumption growth.

The Azerbaijani experience demonstrates that resource productivity can be enhanced through technology, yet long-term sustainable outcomes are achievable only through need-oriented planning and state coordination. For example, modernized irrigation systems in agriculture, integrated with renewable energy solutions, reduce water use by 15–20% while increasing productivity. This empirically confirms the principles highlighted in the present study: technologically mediated resource expansion and empirically defined human needs are key to optimizing welfare in a post-liberal context (Qasımli *et al.* 2022).

This analysis shows that Azerbaijan:

1.Has sufficient data to empirically measure and optimize human needs.

2.Can enhance resource-use efficiency by synchronizing technology and state policies.

3.Offers concrete mechanisms for sustainable development under a post-liberal, need-oriented economic framework (NEM).

Conclusion

This study has systematically examined the economic efficiency of green technologies through a post-liberal analytical framework that reconceptualizes natural resources as technologically expandable and human needs as empirically finite. By integrating cross-sectoral empirical evidence from energy, food, and water systems with Haydar Baş's National Economy Model (NEM), the research directly challenges the classical and neoclassical assumption that economic stability depends on perpetual demand expansion and that unlimited human wants must inevitably confront finite natural resources (Baş, 2013; IEA, 2021; REN21, 2022).

The empirical findings provide robust evidence that human needs exhibit clear and measurable saturation thresholds. Across high-income and advanced industrial economies, per-capita energy consumption stabilizes at approximately 7,500 kWh per year, caloric intake plateaus around 3,200 kcal per person per day, and water consumption converges near 250 liters per person per day (FAO, 2020; IEA, 2021; World Bank, 2021). Beyond these thresholds, additional resource use generates diminishing marginal welfare returns, empirically validating the finiteness of human needs. This finding undermines demand-driven growth models and provides a quantitative foundation for need-oriented economic planning grounded in observable consumption behavior rather than abstract utility maximization.

In contrast, the analysis demonstrates that resource availability is not a fixed physical constraint but a dynamic, technologically mediated variable. Renewable energy potentials - particularly solar and wind - exceed current global demand by orders of magnitude, yet remain underutilized due to institutional, financial, and policy barriers rather than physical scarcity (REN21, 2022; IEA, 2021). Energy efficiency gains, recycling systems, and

circular economy practices further expand effective resource capacity without proportional increases in material extraction. The observed decoupling of economic output from resource inputs - illustrated by a 36% reduction in EU energy intensity between 2000 and 2020 alongside sustained GDP growth - provides compelling empirical confirmation that technological innovation can reconcile economic activity with ecological constraints (IEA, 2021).

The theoretical integration of post-liberal economics with the National Economy Model yields a coherent and empirically defensible framework for sustainable economic governance. Within this configuration, economic efficiency is redefined not as the maximization of consumption but as the optimization of resource allocation to meet socially defined, finite human needs. State-coordinated monetary sovereignty, as articulated in NEM, enables large-scale investment in green technologies without reliance on interest-driven capital accumulation, thereby reducing systemic instability and speculative demand cycles. Markets retain an important role as mechanisms for allocation and innovation diffusion, but strategic public policy provides the institutional guidance necessary to align technological expansion with welfare maximization and ecological resilience.

The policy implications of this framework are substantial. Shifting from demand-expansion strategies toward need-oriented economic planning reduces systemic volatility, mitigates rebound effects, and enhances long-term social welfare. Coordinated green technology policies - such as feed-in tariffs, public investment in renewable infrastructure, and regulatory support for circular systems - emerge not as distortions of market efficiency but as essential instruments for translating technological potential into sustainable outcomes. At the global level, the findings offer a viable pathway for developing economies to achieve self-sufficiency and resilience by leveraging technology-driven resource expansion rather than replicating consumption-led growth trajectories that generate ecological degradation and social inequality.

In conclusion, this research demonstrates that a post-liberal, need-oriented economic model grounded in green technological innovation and institutional coordination is not only normatively desirable but also analytically rigorous and empirically substantiated. By anchoring sustainability in measurable human needs and demonstrable technological capacity, the proposed framework reconciles economic efficiency with ecological stability and social equity. It thus provides a credible and policy-relevant pathway toward long-term economic resilience and sustainable development in both advanced and emerging economies.

Declaration

Credit Authorship Contribution Statement:

Mahabbat Mammadov: Conceptualization, Supervision, Investigation, Methodology, Formal analysis, Conceptualization, Theoretical analysis, Methodology, Writing – review and editing, Supervision, Funding acquisition.

Kamala Mammadova: Conceptualization, Methodology, Software, Formal analysis, Data curation, Validation, Writing – review and editing, Visualization.

Ruslan Aliyev: Supervision, Formal analysis, Methodology, Data curation, Validation, Writing – review and editing, Funding acquisition.

Declaration of Competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies: The authors declare that they have not used generative AI and AI-assisted technologies in the writing process before submission, but only to improve the language and readability of their paper and with the appropriate disclosure.

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